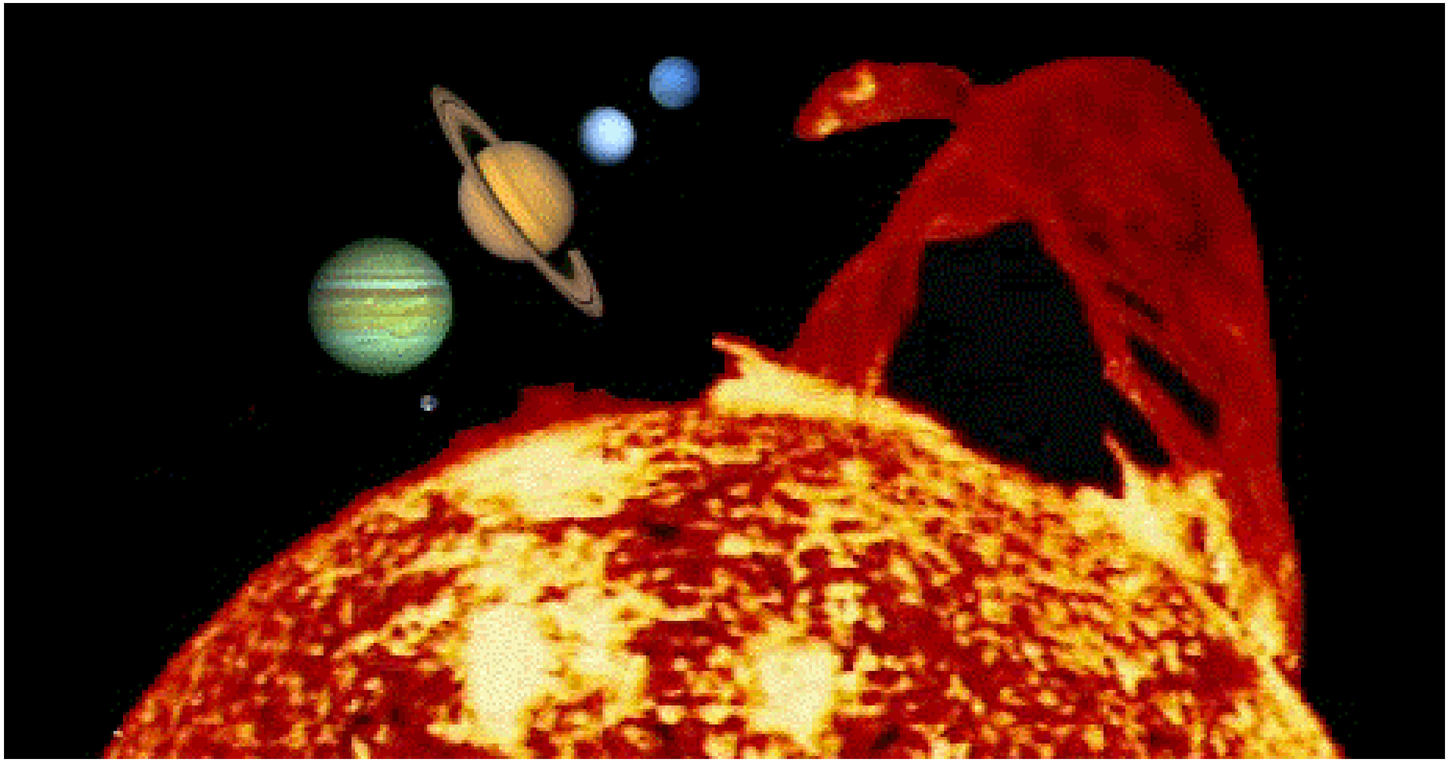
# Perspective and Scale Size in Our Solar System



# Notes

- Clue Session in Mary Gates RM 242 Mon 6:30 – 8:00
- Read Lang Chpt. 1
- Moodle Assignment due Thursdays at 6pm (first one due 1/17)
- Written Assignments due Tues lab section (first one due 1/15)

# Space and Space Travel

## Why do we care about the Space Environment?

1) Space is lethal and our changing atmosphere and space environment are our cocoon.

- *X-Rays and UV radiation are (usually!) stopped in our atmosphere.*
- *Cosmic Rays ( particles, mostly protons from Sun and Space) enter our atmosphere.*
    - *8% of our radiation exposure comes from Cosmic Rays*
    - *An 12 hr airplane flight is equivalent to 1/2 a chest X-Ray*
    - *Cosmic Rays may produce mutations and be important for evolution.*

# Space and Space Travel

## Why do we care about the Space Environment?

2) Planetary Hazards:

- *Space has evolved over billions of years (impacts-supernovae)*

3) Technology depends on space:

- *Communications Satellites*
- *Weather Prediction (Galveston-1900, Children's Blizzard-1888)*
- *Global Location with GPS*
- *Global Remote Sensing (deforestation, fires, pollution, ozone)*
- *WIFI world (XM, Sirius, DirectTV, etc.)*

# Space and Space Travel

## Why do we care about Space Travel?

1) We're Explorers!

- *Space and planetary environments are hostile to us and our robot probes.*
  - *We dodged a bullet with Apollo, Russia didn't at Mars.*
  - *Weightlessness, radiation, and local conditions (Temperature, Pressure, etc.) are big concerns.*
- *Space is BIG.*
  - *Current methods of travel require long periods to reach targets.*
- *Expansion of Human Habitats.*
  - *Other environments in the solar system. Can we survive there?*
  - *Is life (or conditions for life) present anywhere else?*

# Space and Space Travel

## Why do we care about the Space Travel?

2) Space Travel is Expensive:

- *Space Shuttle costs $10000 per pound!*
- *"Cheap" access to space costs $1000 per pound!*

3) Space Travel is Inefficient and Slow:

- *>90% of most missions is composed of fuel.*
- *Even our fastest spacecraft take years to get anywhere (Voyager 2 took ~12 years to reach Neptune)*
- *We must rely on gravity once we launch*

# Space and Space Travel

## Why do we care about the Space Travel?

4) Power and Communications are Difficult:

- *Solar power doesn't work well in the outer solar system.*
- *Neptune is 8 hours (round trip) away by radio*
- *Communications requires large, expensive networks of radio telescopes. (the Deep Space Network)*

5) New Technologies are Being Developed:

- *Understanding what is needed requires knowing what the problems are…..*

# Our Local Inventory:

## What makes up our star system?

1) A Single central star of type “G” (yellow-dwarf).

2) Two *sub-stellar* giant planets. ***(Jupiter & Saturn)***

3) Two *icy-gas* hybrid planets. ***(Uranus & Neptune)***

All of the above planets have large systems of satellites; some planet sized. *(Io, Europa, Ganymede, Callisto, Titan, and Triton)*

4) Four much smaller rocky planets. ***(Mercury, Venus, Earth, & Mars)***

5) Two areas of failed planetary debris

a) one rock based ***(Asteroid Belt between Mars and Jupiter)***

b) one ice-based ***(Kuiper Belt starting at Neptunes orbit)*** .

6) Several “Dwarf” Planets. ***(Pluto)***

7) An extended distribution of ejected debris. ***(Oort Cloud well past Pluto)***

# The Sun and the Solar System

Any study of the solar system must start with the Sun…..

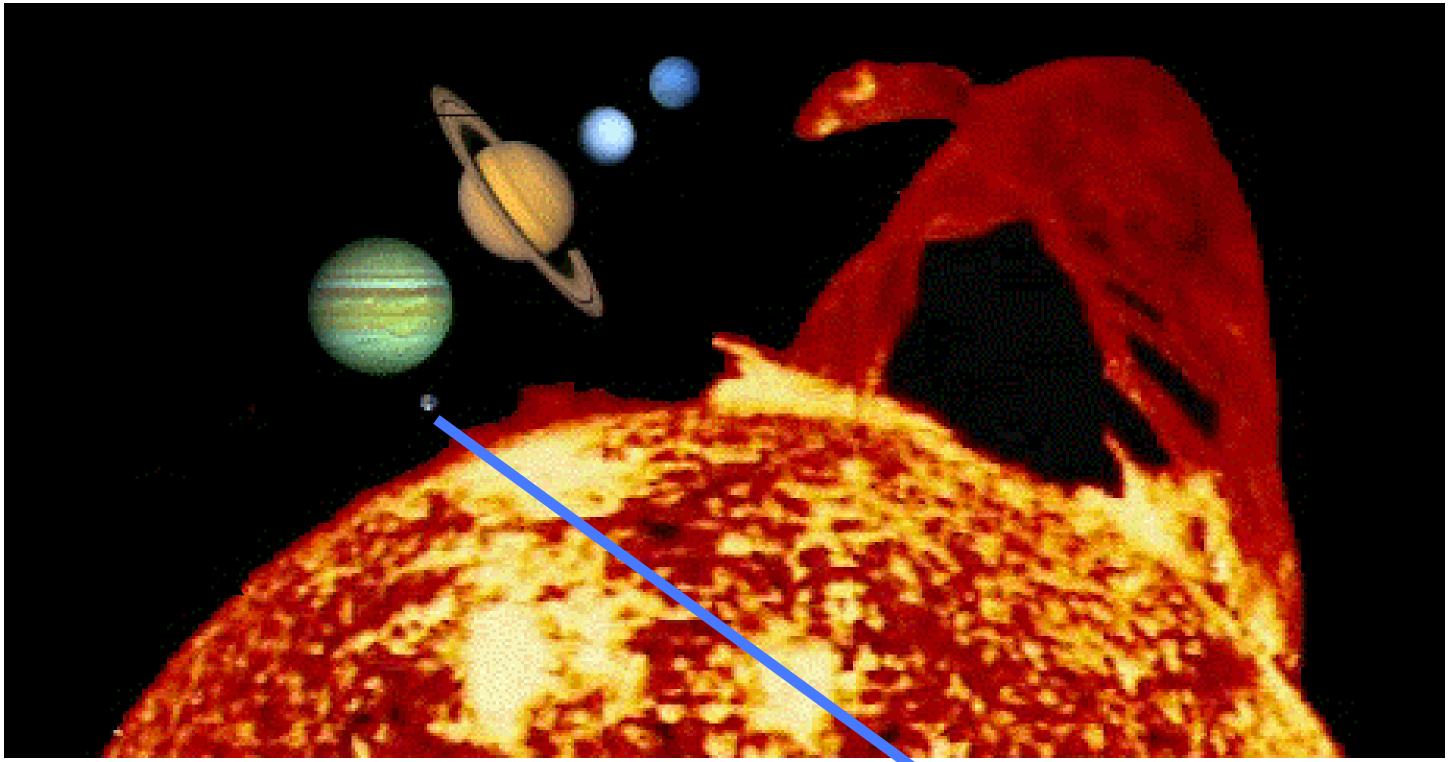
1) The sun contains 99.9% of all the mass in the solar system (Jupiter has most of the remaining 0.1%)

2) The sun dominates energy (and light) production at all frequencies (except in radio waves where *human activity* is stronger!)

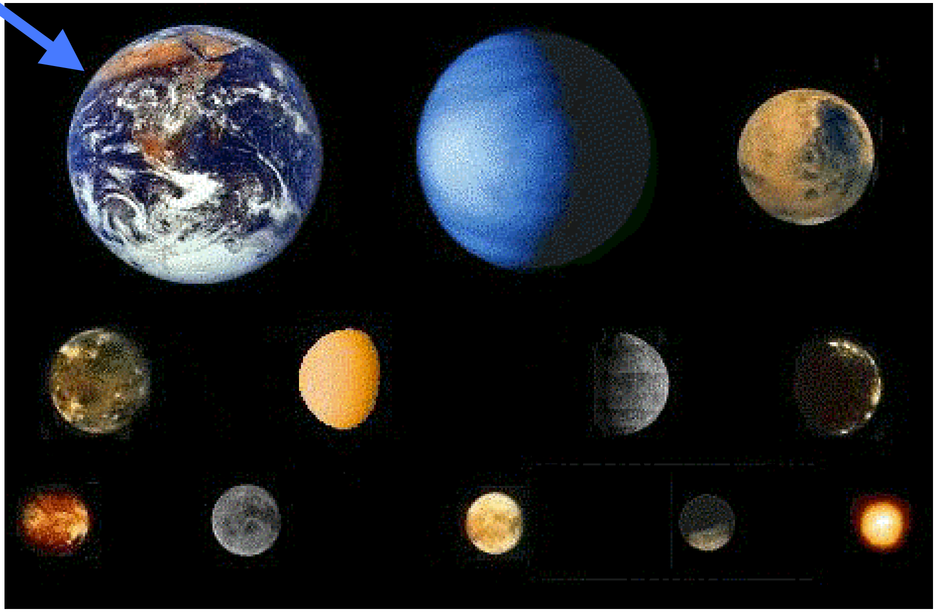
3) Solar energy largely determines the temperatures of every object in the solar system.

4) Material from the Solar Atmosphere is the dominant component of interplanetary space.

Compared to the Sun, the planets are nearly inconsequential…..



The Sun Dominates the Solar System.



The places *we* are most interested in don't add up to very much……

# Exploring our Star System How and Where?

## History is Written in what we see:

*The distribution, composition, and evolution of material in the solar system tells us how we got from a cold cloud of gas & dust to the present:*

1) How did the Sun form and evolve?
2) How do planets form and where?
3) What does the distribution of planets and debris tell us about the early solar system?
4) How do planets change with time and what are the processes involved?
5) How does the interaction with the Sun affect conditions on a planet on various time scales?
6) What does our system tell us about others?

# Scales in the Solar System

## The Solar System is characterized by extremes:

1) The *very hot* to the *very cold*
2) The *very big* to the *very small*
3) The *very dense* to the *very tenuous*
4) The *very close* to the *very distant*
5) The *very numerous* to the *very unique*
6) The *very fast* to the *very slow*

# Our Local Inventory:

## Where to learn more?

We'll return to the members of the solar system later, but to learn more about the planets (perhaps for your writing assignment…) go to:

www.seds.org/nineplanets/nineplanets

www.solarviews.org

# Scientific Notation:

Scientific Notation is a shorthand way of writing and multiplying large (and small) numbers.

| | | | |
|---|---|---|---|
| 0.000000001 | $10^{-9}$ | Nano (n) | (billionth) |
| 0.000001 | $10^{-6}$ | Micro (μ) | (millionth) |
| 0.001 | $10^{-3}$ | Milli (m) | (thousandth) |
| 1 | $10^{0}$ | Unity | |
| 1000 | $10^{3}$ | Kilo (k) | (thousands) |
| 1,000,000 | $10^{6}$ | Mega (M) | (millions) |
| 1,000,000,000 | $10^{9}$ | Giga (G) | (billions) |
| 1,000,000,000,000 | $10^{12}$ | Terra (T) | (trillions) |

To do numbers that are not divisible by ten, we ***multiply*** by an exponential number.

$4,275,000,000 = 4.275 \times 10^{9}$ ***or*** $0.000374 = 3.74 \times 10^{-4}$

# Using Scientific Notation:

To ***multiply*** numbers using scientific notation we ***add*** the exponents.

$10^3 \times 10^{-9} = 10^{(3) + (-9)} = 10^{-6}$

$10^2 \times 10^5 = 10^{(2) + (5)} = 10^7$

To ***divide*** numbers using scientific notation we ***subtract*** the exponents.

$10^3 \div 10^{-9} = 10^{(3) - (-9)} = 10^{12}$

$10^2 \div 10^5 = 10^{(2) - (5)} = 10^3$

To ***add or subtract*** numbers using scientific notation we work ***in front of*** the exponents.

$3.0 \times 10^2 + 2.6 \times 10^5 = 2.603 \times 10^5$

$1.0 \times 10^5 - 7.0 \times 10^2 = 0.993 \times 10^5$

# Scientific Notation /Units Example

How long does light take to travel from the visible surface of the Sun to the Earth?

Distance from Sun to Earth ***D = 150,000,000 km***

***This is also known as one astronomical unit (AU)***

In Scientific Notation $\boldsymbol{D = 1.5 \times 10^{8}\ \text{km}}$

There are 1000 ($10^3$) meters in one kilometer:

Hence, in Meters $\boldsymbol{D = 1.5 \times 10^{8}\ \text{km} \times (10^{3}\ \text{m/km})}$

$\boldsymbol{= 1.5 \times 10^{(8+3)}\ \text{m}}$

$\boldsymbol{= 1.5 \times 10^{11}\ \text{m}}$

# Scientific Notation/Units Example

The Speed of Light $c = 3 \times 10^{8}$ m/s

**The time = distance/speed = *D/c***

**time = D/c** $= (1.5 \times 10^{11}\ m) \div (3 \times 10^{8}\ m/s)$

$= (15 \times 10^{10}\ m) \div (3 \times 10^{8}\ m/s)$

$= 15/3 \times 10^{(10-8)}\ (m/(m/s))$

$= 5 \times 10^{2}\ s = 500\ s$

60 s per min, *so* ***time*** $= 500\ s \times (min / 60\ s)$

$= 8.33\ min$

# Scientific Notation/Units Example

Density of Water

***Density is mass per volume***

For water: 1 gram / centimeter$^3$ (1g/cm$^3$)

What is this in kilograms / meters$^3$ ?

We know that 1000 ($10^3$) g per kg and 100 ($10^2$) cm per meter, hence

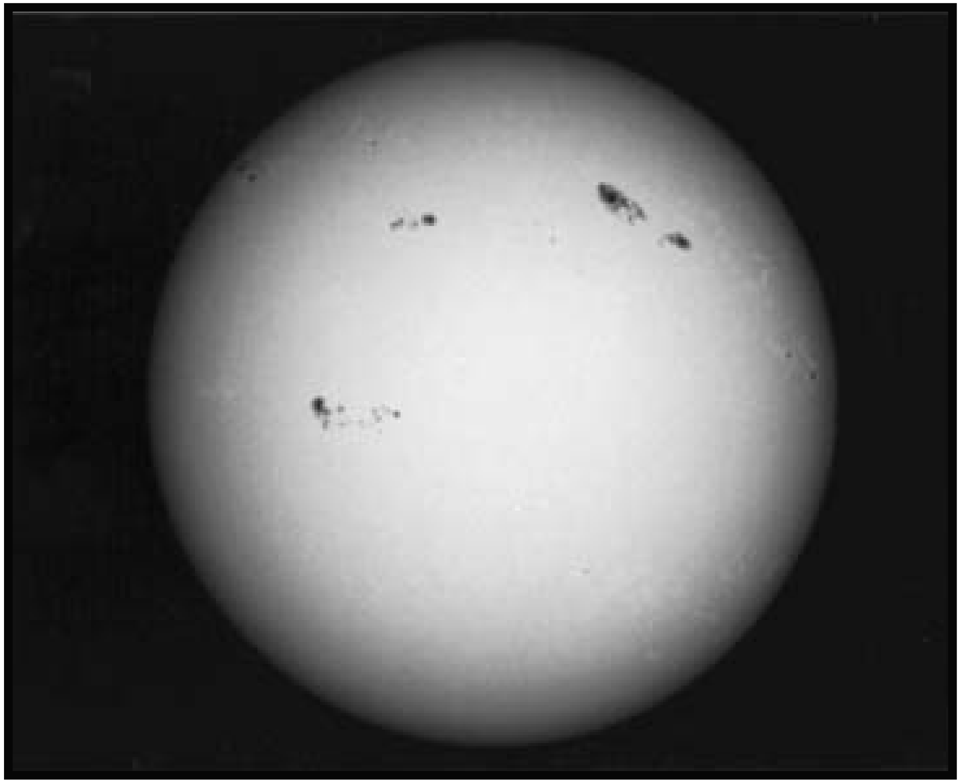
$$1\text{g/cm}^3 = (1\text{g x (kg}/10^3\text{g)}) \div (\text{cm}^3 \text{ x (m}/10^2\text{cm)}^3)$$

$$= (1/10^3) \text{ kg} \div (1/10^{(2) \text{ x } 3}) \text{ m}^3$$

$$= 10^{-3} \text{ kg} \div 10^{-6} \text{ m}^3$$

$$= 10^{(-3) - (-6)} \text{ kg/m}^3 = 10^3 \text{ kg/m}^3$$

# Comparing the Sun and Earth

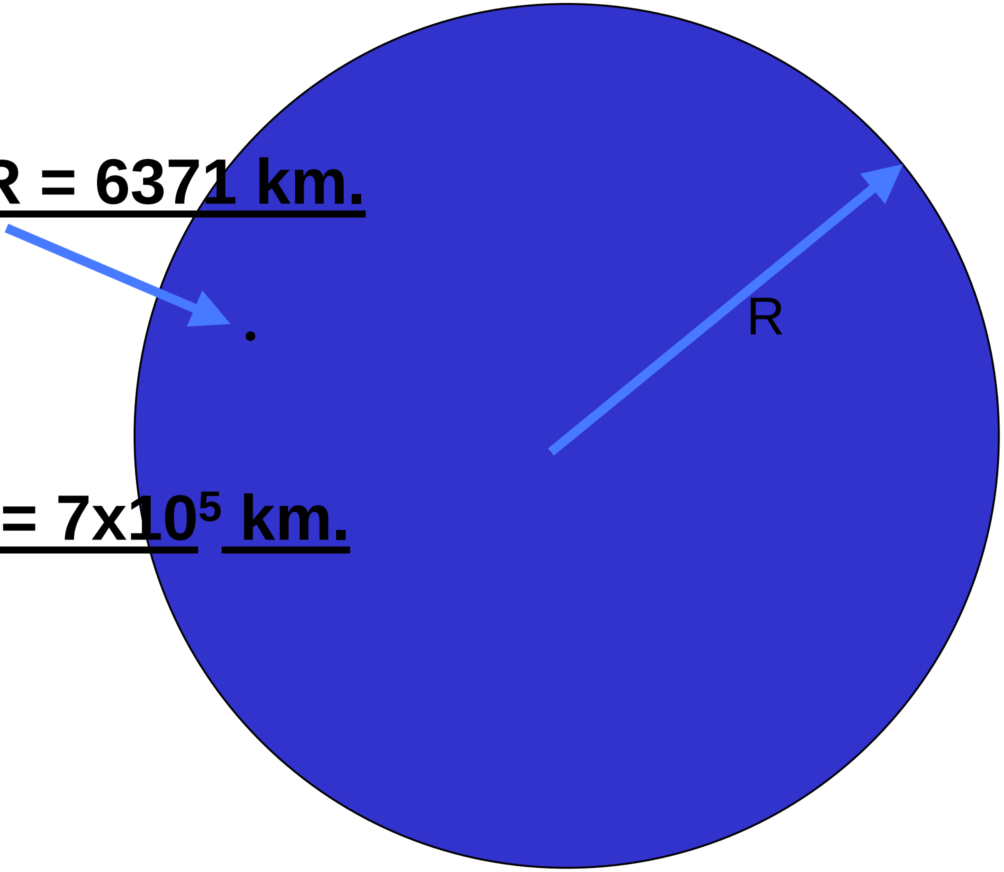


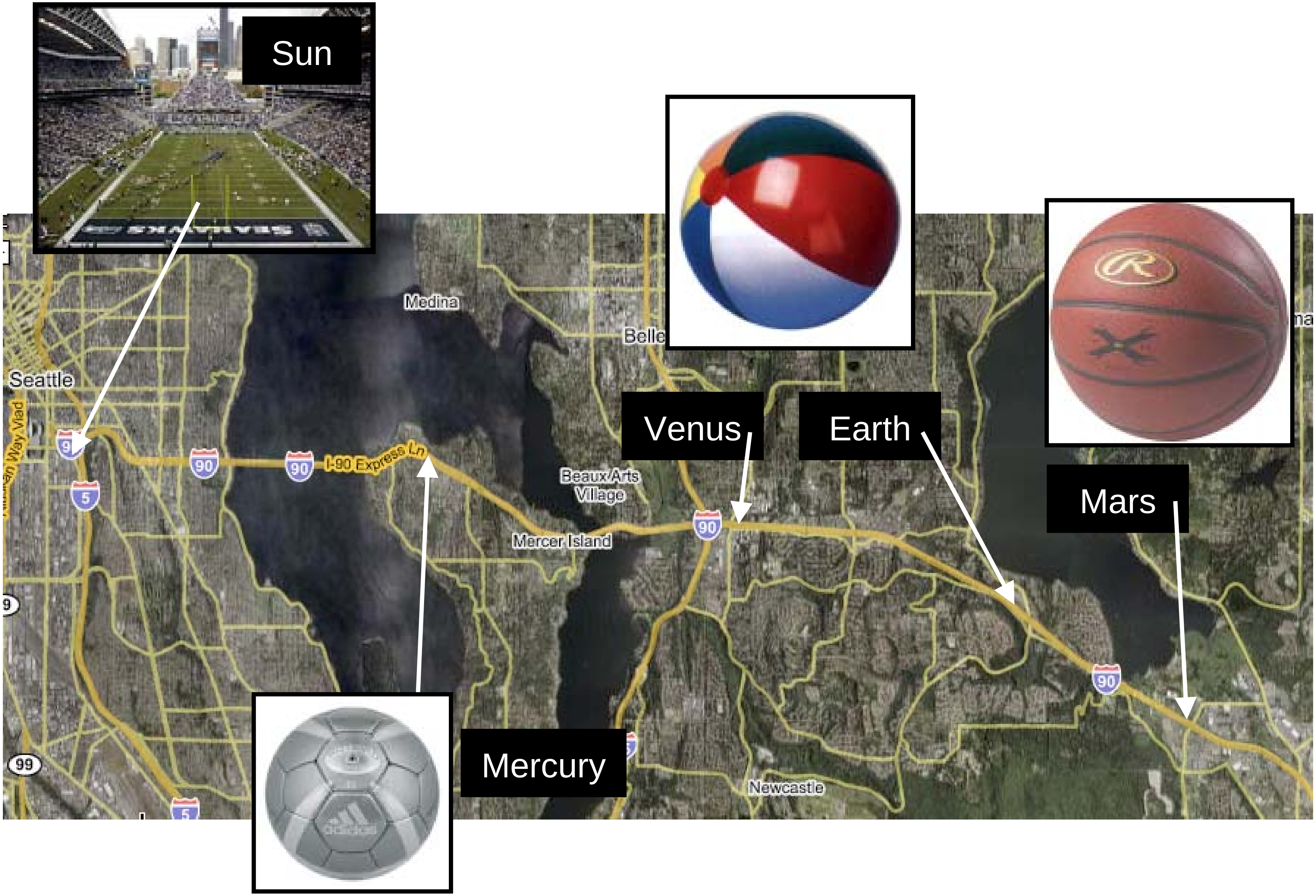
# Comparing the Sun and Earth

## Size:

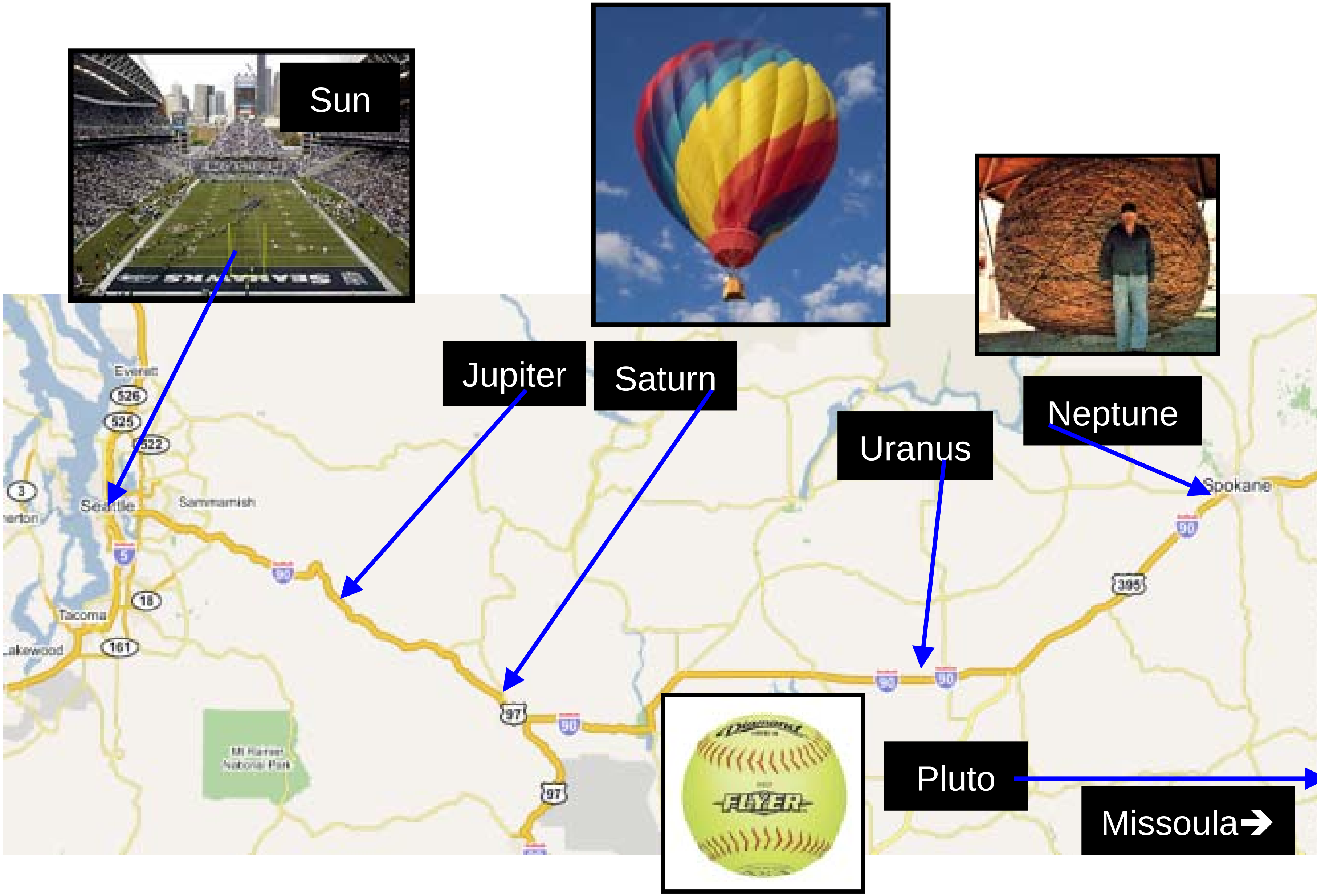
1) The radius of the Earth is **R = 6371 km.**

2) The radius of the Sun is **R = 7x$10^5$ km.**





Sun
Venus
Earth
Mars
Mercury
Medina
Seattle
Mercer Island
Beaux Arts
Village
I-90 Express Ln
Newcastle


Sun
Jupiter
Saturn
Uranus
Neptune
Pluto
Missoula→
Everett
Seattle
Sammamish
Tacoma
Lakewood
Spokane
SEAHAWKS
FLYER

# Comparing the Sun and Earth

## Mass:

1) The mass of the Sun is $M = 2 \times 10^{30}$ kg
2) The mass of the Earth is $M = 6 \times 10^{24}$ kg
3) The ratio of Sun to Earth = $3.3 \times 10^{5}$

If the Sun weighed as much as the aircraft carrier independence………

The Earth would only weigh as much as two members of its crew….

# Comparing the Sun and Earth

## Density:

1) The Density of the Sun is ***D = 1.4 g $cm^{-3}$***
2) The Density of the Earth is ***D = 5.5 g $cm^{-3}$***

*1 paperclip* weighs about *1 Gram (g)*

*1 cubic centimeter ($cm^{-3}$)* is about the size of a *Sugar Cube*

*Water has a density of 1 g $cm^{-3}$ while Lead is 10.8 g $cm^{-3}$*

# Comparing the Sun and Earth

## Composition:

### Earth (Full)

| | |
|---|---|
| 34.6% | Iron |
| 29.5% | Oxygen |
| 15.2% | Silicon |
| 12.7% | Magnesium |
| 2.4% | Nickel |
| 1.9% | Sulfur |

### Earth (Air)

| | |
|---|---|
| 78% | Nitrogen |
| 21% | Oxygen |
| 0-4% | Water |
| 1% | Argon |
| 0.035% | $CO_2$ |
| 0.0017% | Methane |

### Sun

| | |
|---|---|
| 92.1% | Hydrogen |
| 7.8% | Helium |
| 0.1% | Carbon/oxygen |
| 0.001% | Iron |

# Comparing the Composition of the Earth and Planets:

## Earth

| | |
|---|---|
| 34.6% | Iron |
| 29.5% | Oxygen |
| 15.2% | Silicon |
| 12.7% | Magnesium |
| 2.4% | Nickel |
| 1.9% | Sulfur |

## Jupiter

| | |
|---|---|
| 92.1% | Hydrogen |
| 7.8% | Helium |
| 0.1% | Carbon & Oxygen |
| 0.001% | Iron |

## Neptune

| | |
|---|---|
| 83% | Hydrogen |
| 15% | Helium |
| 2% | Methane |
| (Atmosphere) | |
| ?? | Water Ice |
| ?? | Silicon |
| ?? | Iron |
| ?? | Oxygen |
| (Interior) | |

Jupiter is almost exactly like the Sun, while the Earth, and to a lesser degree, Neptune are different.

# Comparing the Sun and Earth

## Time and Evolution:

### The Earth

| | |
|---|---|
| 100-10000 sec. | Electrical Disturbances/Storms |
| $10^4$-$10^5$ sec. | Day-Night cycle - Tides |
| $10^7$ sec. | Seasons |
| $10^{11}$ - $10^{12}$ sec. | Ice Ages/Climate Shifts |
| $10^{15}$ - $10^{16}$ sec. | Continent Drift/Magnetic Field/Life |
| $10^{17}$ sec. | **Age of Earth (4.5 billion years)** |

The most significant changes to surface conditions on the Earth were brought about by loss of atmospheric constituents and the emergence of life.

# Changes in the Earth's Atmosphere

## Time and Evolution:

### The Early Earth

- Atmosphere similar to Solar Composition
- 100x thicker than today
- Hydrogen-Helium
- 4.5-3.5 billion years

### The Young Earth

- Hydrogen/Helium Lost
- Oceans form/ $CO_2$ from Volcanic Activity
- $CO_2$ dissolved in Oceans
- 3.5-0.5 billion years ago

### The Living Earth (0.5 byr-Present)

- Nitrogen Dominates as $CO_2$ is lost/Modern density
- Plants evolve photosynthesis-Oxygen Balloons-Feedback with Sun's evolution.
- Animals adapt to $O_2$ metabolism-move to land
- $O_2$ in atmosphere: life's smoking gun/Impossible without

# Comparing the Sun and Earth

## Time and Evolution:

**The Sun**

| | |
|---|---|
| 10000 sec. | Convection at visible surface |
| $10^5$ - $10^6$ sec. | Flares-Solar Events-Oscillations |
| $2x10^6$ sec. | Solar Rotation |
| $10^7$ - $10^8$ sec. | Magnetic Cycle |
| $10^{15}$ - $10^{16}$ sec. | Energy Transport- Changes in Core |
| $10^{17}$ sec. | **Age of Sun (4.5 billion years)** |
| $2x10^{17}$ sec. | Sun a Red Giant/Stellar Death |

# Comparing the Sun and Earth

## Temperature:

| Earth | | Sun | |
|---|---|---|---|
| Surface | 300K (average ground) | Surface | 5000-$10^4$K (visible) |
| Atmosphere (ground to top) | 300-1000K | Atmosphere (Corona) | 2 million K |
| Interior | 3000-5000K | Core | 15 million K |

$$K = 273 + (°F - 32)/1.8$$

273 K = 32°F, 373 K=212° F, and 273°K = 0°C